IDLE CONTROL SYSTEM FOR FUEL CELL VEHICLE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an idle control system for a fuel cell vehicle, and in particular relates to an idle control system for a fuel cell vehicle, which is installed in a hybrid-type power supply provided with a fuel cell and a power storage device which is recharged by generated current from the fuel cell.

Description of the Related Art

Heretofore there is known a fuel cell vehicle provided with a solid polymer membrane-type fuel cell, in which the responsiveness of the output supply to each part of the vehicle is increased by providing a power storage device comprising for example a battery or a capacitor and the like, in order to supplement the output responsiveness of the fuel cell accompanying the gas supply of hydrogen gas as a fuel and air as an oxidizing gas.

As such a fuel cell vehicle there is for example one disclosed in Japanese Unexamined Patent Application, First Publication No. 2001-359204, which is provided with an idle control system which detects an idle state where it is possible to stop power generation of the fuel cell, and stops power generation of the fuel cell, and resumes power generation of the fuel cell when the state of charge of the power storage device is less than a predetermined state of charge.

However, in the conventional technology, the target amount of power generated in the case of resuming power generation of the fuel cell is set depending on the state of

charge of the power storage device and the expected power consumption of the electrical load of the vehicle. Therefore, the amount of power generated by the fuel cell fluctuates depending on the state of the electrical load, and hence there is no appreciable increase in the efficiency of power generation by the fuel cell. Also, there is concern that the amount of noise generated by the air supply compressor which supplies the reaction gas air to the fuel cell, fluctuates depending on the target amount of power generated by the fuel cell.

In particular, in cases where the state of charge of the power storage device is low, and where the expected power consumption of the electrical load of the vehicle is high, the target amount of power generated by the fuel cell is increased. However, a supply of reaction gas to match to the increase of the amount of power generated by the fuel cell is necessary, and hence the power required by the air supply compressor also increases. Therefore, as the amount of power generated by the fuel cell becomes greater, the power consumed in order to drive the compressor is increased, and there have been problems with a reduction in the overall efficiency of power generation.

SUMMARY OF THE INVENTION

The present invention takes the above situation into consideration, with the object of providing an idle control system for a fuel cell vehicle in which it is possible to improve fuel consumption efficiency by increasing the overall power generation efficiency.

In order to solve the above problem, a first aspect of the present invention provides an idle control system applicable to a fuel cell vehicle (for example, the fuel cell vehicle 1 in the embodiment), wherein the fuel cell vehicle comprises a fuel cell (for example the fuel cell 3 in the embodiment) to which reaction gases are supplied by an air supply compressor (for example, the air compressor 8 in the embodiment) and by a hydrogen supply device (for example, the hydrogen tank 9 in the embodiment) to generate power, a

driving motor (for example, the driving motor 5 in the embodiment) which is driven by a current generated by the fuel cell, and a power storage device (for example, the capacitor 4 in the embodiment) which is charged by the current generated by the fuel cell, and the idle control system for controlling the fuel cell vehicle according to driving modes wherein when it is determined that the fuel cell vehicle is in a normal driving state (for example, a normal power generation mode M01, in the embodiment), and not in an idle state, the control system (for example the control unit 7 in the embodiment) drives the fuel cell to generate electric current corresponding to a required power for driving the driving motor and the auxiliary equipment; when it is determined that the fuel cell vehicle is in a predetermined idle state (for example, an idle stop mode M02in the embodiment), the control system (for example the control unit 7 in the embodiment) stops the compressor for stopping the fuel cell to stop power generation of the fuel cell; and while the fuel cell vehicle is in a predetermined idle state (for example, an idle charge mode M03 in the embodiment), when it is determined that the state of charge of the power storage device decreases below a predetermined state of charge of the power storage device (for example the low load zone L in the embodiment), a control system (for example, the control unit 7 in the embodiment) drives the fuel cell to generate a current for charging the power storage device.

According to the first aspect, fuel cell is efficiently driven depending on the driving state of the fuel cell vehicle. When the fuel cell vehicle is in a normal driving state, the fuel cell is activated such that the fuel cell can supply the required current for the driving motor and auxiliary equipment. When the fuel cell vehicle is in a predetermined idle stop state (for example in the idle stop mode M02 in the embodiment), power generation by the fuel cell is stopped by stopping the air compressor. In addition, while the fuel cell vehicle is in the predetermined idle state, and when the state of charge of the

power storage device falls below the predetermined value, the fuel cell is driven so as to execute power generation at an optimum generation efficiency, and the power storage device is charged by the current generated by the fuel cell.

According to the second aspect of the present invention, in an idle control system of a fuel cell according to the first aspect, the power generation efficiency of the fuel cell system is defined by {(total electric power generated by the fuel cell–electric power consumed by the compressor for supplying the reaction gas to fuel the cell)/total electric power generated by the fuel cell}.

According to the third aspect, in the idle control system according to the first aspect, the predetermined idle state is determined based on an operating state of an accelerator pedal by a driver.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic block diagram showing an idle control system for a fuel cell vehicle according to an embodiment of the present invention.

FIG. 2 is a flow chart showing idle stop and idle charge control of the idle control system in FIG. 1.

FIG. 3 is a graph showing the relationship between generated current and overall efficiency.

FIG. 4 is a state transition diagram of the modes of the idle control system in FIG. 1.

FIG. 5 is a block diagram showing the idle control system for fuel cell vehicle according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Hereunder an embodiment of an idle control system for a fuel cell vehicle according to the present invention is described with reference to the appended drawings. FIG. 1 is a schematic block diagram of a fuel cell vehicle 1, which is provided with an idle control system 2 for a fuel cell vehicle according to the embodiment of the present invention. The idle control system 2 according to this embodiment is provided with a hybrid-type power supply unit comprising for example a fuel cell 3 and a capacitor 4, being a power storage device.

The fuel cell 3 is integrally formed by multi-layer lamination of unit fuel cell comprising a solid polymer electrolyte membrane sandwiched between an anode electrode and a cathode electrode. A high-pressure hydrogen tank 9, for example, is connected to the anode electrode of the fuel cell 3, and hydrogen is supplied from the hydrogen tank 9 to the anode electrode. Also, an air compressor 8 is connected to the cathode electrode of the fuel cell 3, and air (oxygen) is supplied from the air compressor 8 to the cathode electrode. When hydrogen is supplied to the reaction surface of the anode electrode, the hydrogen is ionized there and migrates to the cathode electrode through the solid polymer electrolyte membrane. Electrons created at this time are taken out to an external circuit and used as direct current electrical energy.

A current limiting unit 6 is connected to the fuel cell 3. This current limiting unit 6 is also connected to the capacitor 4, a driving motor 5, auxiliary equipment (such as air conditioning and head lamps mounted on the vehicle 1) 10, and an air compressor motor 11, and limits the power from the fuel cell 3 as required, to supply power to these items 4, 5, 10, and 11. The air compressor motor 11 is coupled to the air compressor 8, and the air compressor 8 is driven by operating the air compressor motor 11. Consequently, part of

the power generated by the fuel cell 3 is used to drive the air compressor 8, which supplies the reaction gas (oxidizing gas).

The capacitor 4 is for example an electric double layer capacitor, charged by a current generated by the fuel cell 3, and is provided with the function of assisting the power generation of the fuel cell 3 by supplying power stored in the capacitor 4 to the driving motor 5 and the auxiliary equipment 10.

The driving motor 5 connected to the fuel cell 3 and to the capacitor 4 produces driving power from the power supplied from the fuel cell 3 and the capacitor 4. This driving power is transmitted to driving wheels (not shown in figure) through a reduction or a transmission T/M, to thereby drive the fuel cell vehicle 1.

Also, when the fuel cell vehicle 1 decelerates and driving power is transmitted from the driving wheels to the driving motor 5, the driving motor 5 functions as a power generator, and generates a so-called regenerative braking force. As a result, the kinetic energy of the vehicle body can be recovered as electrical energy, and the electrical energy is stored in the capacitor 4.

A control unit 7 is connected to the fuel cell 3, a current limiting unit 6, the driving motor 5, and the air compressor motor 11. This control unit 7 calculates the required power, based on an accelerator pedal depression amount Ap and the vehicle speed Vc and so on, and controls the respective control signals to the fuel cell 3 and current limiting unit 6, the driving motor 5, and the air compressor motor 11, based on the calculated power.

As shown in FIG. 4, the fuel cell 3, the current limiting unit 6, and the driving motor 5 are switched between a normal power generation mode M01, an idle stop mode M02, and an idle charge mode M03, according to instructions from the control unit 7. This will be discussed later.

FIG. 2 is a flow chart showing idle stop and idle charge control according to the present embodiment. In step S02, the control unit 7 performs idle stop determination. This determination determines whether the speed Vc of the fuel cell vehicle 1 is lower than a predetermined value, whether the expected power consumption of the driving motor 5 is lower than a predetermined value, whether the power of the electrical load (driving motor 5, auxiliary equipment 10) is lower than a predetermined value, and so on. Then, in step S04, it is determined whether or not idle stop is possible.

In the case where it is determined in step S04 that idle stop is not possible, the control unit 7 controls the normal power generation mode M01, and in step S06 calculates the normal target generation current. In this normal power generation mode M01, the control unit 7 obtains the power required by the driving motor 5 from the accelerator pedal depression amount Ap, and also obtains the power required by the air conditioning and other auxiliary equipment 10. Then, in order to generate both required powers, the control unit 7 obtains the power required by the air compressor motor 11 necessary to drive the air compressor 8, and obtains the total power required after adding all these power requirements. The control unit 7 obtains a required supply amount of reaction gas necessary for the generation of power by the fuel cell 3 so as to satisfy this total power requirement, and controls the air compressor motor 11 so as to supply this required amount of the reaction gas to the fuel cell 3. Then, the process of this flow is complete.

Consequently, because the generated current of the fuel cell 3 in this normal power generation mode M01 changes according to the demand of the electrical load, the vehicle is driven in zones where the power generating efficiency of the fuel cell 3 is not at optimum conditions.

In the case where it is determined in step S04 that idle stop is possible, in step S08 the control unit obtains the state of charge of the capacitor 4 based on the voltage thereof, and determines whether or not the state of charge is lower than a predetermined value.

In the case where in step S08 the determination is NO, the the control unit 7 controls the idle stop mode M02, and in step S12 controls the stopping of power generation of the fuel cell 3. That is, it sets the rotation speed of the air compressor 8 to zero, and also sets the electrical current instruction for the current limiting unit 6 to zero. In this manner, by stopping the power generation of the fuel cell 3, the hydrogen gas and the oxidizing gas necessary for the generation of power can be reduced, and because there is no need for the power necessary to drive the air compressor 8 and the like in order to supply these reaction gases, fuel consumption efficiency can be improved. In this idle stop mode M02, the supply of power to the electrical load of the vehicle 1 is performed by the capacitor 4. Then, the process of this flow is complete.

In the case where in step S08 the determination is YES, the control unit 7 controls the idle charge mode M03, and in step S10 calculates the most efficient target generation current for the fuel cell 3, and controls power generation at this current. This will be explained using FIG. 3.

FIG. 3 is a graph showing the relationship between the generated current and the overall efficiency. In this graph, the total generated current (A) generated by the fuel cell 3 is on the horizontal axis, the power generation efficiency (%) of the fuel cell 3 is on the left vertical axis, and the power (kW) is on the right vertical axis. Moreover, the power generation efficiency (Δ), the total generated power (●) and the power consumption of the air compressor motor 11 (□) are shown in this graph.

The power generation efficiency shown in the same graph is expressed by the equation below.

Equation 1: Power generation efficiency

=(power actually able to be supplied to the electrical load/total generated power)x100(%)

={(total generated power − power consumption of the compressor motor 11)/total

generated power}x100(%)

Hereunder this equation will be explained. Because one part of the total power

generated by the fuel cell 3 is used by the motor 11 in order to drive the compressor 8 to

supply the reaction gas (air), the power actually able to be supplied to the electrical load is

the power remaining after the power necessary to drive the compressor 8 (power

consumed by the motor 11) has been subtracted from the total generated power.

Consequently, in a zone where the generated electric current is low (zero proximity

zone Z), because the greater part of the generated current is consumed by the compressor

motor 11, power generation efficiency is low.

In a low load zone L where the generated current of the fuel cell 3 is increased to

more than that in the zero proximity zone Z, because the generated power increases

considerably, the proportion of power consumed by the compressor motor 11 is relatively

reduced, and the power able to be supplied to the electrical load also increases. Therefore,

power generation efficiency rises in the low load zone L.

Then, in a high load zone H where the generated current is further increased to

more than in the low load zone L, the generated voltage decreases by the IV (current ·

voltage) characteristic of the fuel cell 3. Therefore, the total power generated by the fuel

cell 3 (voltage x current) does not increase in direct proportion to the generated current,

and the rate of increase of the total power generated decreases.

On the other hand, power consumption of the compressor motor 11, regardless of

the generated current zones Z, L and H, increases almost in direct proportion to the

generated current. Therefore, power generation efficiency in the high load zone H where

the generated current is high, decreases in comparison to the low load zone L.

Consequently, power generation efficiency is the largest in the low load zone L.

In the idle charge mode M03, regardless of the state of the electrical load, because

the fuel cell 3 generates power in an operating zone (low load zone L) with a more

efficient power generation than in a normal operating zone (high load zone H), the

electrical load can be driven while continuing to charge the capacitor 4, and it becomes

possible to further improve fuel consumption efficiency. Moreover, during this power

generation, the amount of reaction gas required is comparatively low, and the noise of the

air compressor 8 can be maintained at a low noise level. Therefore the level of comfort

can be improved. Furthermore, in the case where the amount of power required by the

electrical load is larger than the amount of power generated by the fuel cell 3, there is no

problem because the deficiency in the amount of power generated by the fuel cell 3 is

supplemented by power from the capacitor 4 to supply power to the electrical load.

FIG. 4 is a state transition diagram of the modes in the idle control system 2.

During operation in the normal power generation mode M01, in the case where the

operating conditions for possible idle stop operation as shown in the above steps S02 and

S04 have been met, a transfer to the idle stop mode M02 takes place as indicated by the

arrow P. Then, in the case where the state of charge of the capacitor 4 is lower than a

constant, a transfer to the idle charge mode M03 takes place as indicated by the arrow R,

and charging of the capacitor 4 takes place as mentioned above. Then, in the case where

the state of charge of the capacitor 4 is greater than the constant, a transfer to the idle stop

mode M02 takes place as indicated by the arrow T. Also, in the case where an intent to

accelerate is detected from the accelerator pedal depression amount Ap while in the idle

stop mode M02 or the idle charge mode M03, a transfer to the normal power generation

mode M01 takes place as indicated by the arrows Q and S.

An idle control system for a fuel cell vehicle according to the present invention has

been described in the above embodiment, but the present invention is not limited to this.

For example, it is possible to use a battery instead of a capacitor as a power storage device.

As described above, according to the present invention, fuel consumption

efficiency can be improved by stopping the power generation of the fuel cell when an idle

state is determined, and the fuel cell can be restarted smoothly. Also, because the fuel cell

generates power in a more efficient manner than the normal operating zone when the state

of charge of the power storage device is low, it becomes possible to further improve fuel

consumption efficiency. Moreover, during power generation by the fuel cell, the noise of

the compressor can be maintained at a low noise level, and hence the level of comfort can

be improved.

The present invention will be summarizingly described with reference to FIG. 5.

In the present invention, the control system of the fuel cell vehicle selects a power

generation mode depending on whether the fuel cell vehicle is in an idle state and whether

the state of charge of the power storage device is low or not. The following power

generation modes are selected.

(1) Normal generation mode: when it is determined that the fuel cell vehicle is in a normal

driving mode and not in a idle stop mode, the control system sets the current generated by

the fuel cell depending on the required amount of currents for driving the motor and

auxiliary equipment (electric load, for example, air compressor);

(2) Idle stop mode: when it is determined that the fuel cell vehicle is in an idle stop mode, the control system stops power generation of the fuel cell (that is, the control system sets the current generated by the fuel cell to zero); and

(3) Idle charge mode: when it is determined that the state of charge of the power storage device falls to a low level, and while the fuel cell vehicle is in the idle stop mode, the control system sets the current generated by the fuel cell according to the optimum power generation efficiency of the fuel cell.

Based on the above mode, the generation currents by the fuel cell is determined, and power generation of the fuel cell is executed by controlling amounts of reaction gases comprising air and hydrogen.